

# **Maize (*Zea-maize L.*) Grain Yield Response to Nitrogen Applied at Different Distances Away from the Row**

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**Maize (*Zea-maize L.*) Grain  
Yield Response to Nitrogen  
Applied at Different Distances  
Away from the Row**

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# **Maize (*Zea-maize L.*) Grain Yield Response to Nitrogen Applied at Different Distances Away from the Row**

## **ABSTRACT**

A one percent global increase in nitrogen use efficiency would be worth approximately 1 billion dollars (Raun and Johnson, 1999). It is thus important to apply nitrogen (N) midseason or split applied so as to improve nitrogen use efficiency (NUE) (Tubaña et al., 2008). Also, applying N closer to the plant could improve NUE. This new placement approach may be important in semi-arid to arid climates where mass flow of nitrogen is hindered by low soil moisture. Experimental sites were established at the R.L. Westerman Irrigation Research Station near Stillwater, OK in the spring of 2008 and 2009. In the spring of 2009, one more location was added near Haskell, OK. The R.L. Westerman Irrigation Research Station is located on a Port-Oscar silt loam (fine-silty, mixed, super active, thermic Cumulic Haplustolls), and the site near Haskell, OK (dry-land) is located on a Taloka silt loam (Fine, mixed, active, thermic Mollic Albaqualfs). Traditionally midseason fertilizer applications in corn (*Zea maize L.*) are placed down the center of 76 cm rows, making the distance of application 38 cm from the plant. This

study evaluates midseason (V8 to V10) liquid urea ammonium nitrate (UAN) rates (45, 90, 134, and 224 kg N ha<sup>-1</sup>) applied at different distances (0, 10, 20, 30 and 38 cm within the row; as well as specifically applying UAN (28%) directly to the plant stalk 13 cm vertically from the soil surface along a horizontal plane.

The findings suggest that placing midseason application (V8 to V10) of UAN (28%) closer to the plant can increase corn grain yields. Furthermore corn grain yields were highest when midseason applications were placed at the base of the plant (0 cm) and at the 10 cm application distances. These results suggest that if producers are going to apply mid-season N, they need to apply it closer to the row and avoid applying N in the middle of the row which is currently the most commonly accepted practice in corn production.



# CHAPTER I

## INTRODUCTION

Arable land is dwindling on a global scale due to increased urbanization and desertification; compounded by the fact that world population is expected to reach 9.1 billion by 2050 (United Nations, 2005). The agricultural community must be prepared to reach these production demands while maintaining environmental responsibility, conserving non-renewable resources all while continuing to be a fiscally productive sector of the world economy. Developed nations must lead the way with new science and innovation, such as precision placement of nutrients, specifically nitrogen fertilizers, in an effort to improve nitrogen use efficiency (NUE) on a global scale. Such a task can only be accomplished by managing individual production units on a sub meter scale (Solie et al., 1999).

Improving NUE is a parody because nitrogen fertilizer is the most limiting essential nutrient next to water in agricultural production. However, if nitrogen is used in excess it can be a costly mistake as excess nitrogen fertilizer in the form of nitrate ( $\text{NO}_3^-$ ) can be leached or end up in surface water. Nitrate leaching can cause

eutrophication; a process where water bodies can become impaired by excess nutrient input causing anoxic conditions which ultimately lead to the death of aquatic organisms (United States Geological Survey , 2008). There have been several monetary figures estimating nitrogen loss ( $\text{NO}_3^-$ ) within the Mississippi River drainage basin. Booth (2009) estimated that each spring 391 million dollars in nitrogen fertilizer flows down the Mississippi River, (Booth, 2009) while Malakoff (1998) estimated an annual figure of 700 million dollars, with considerable amounts of that excess nitrogen coming from crop production in the upper Midwest.

Additionally over application of nitrogen fertilizers is costly, especially with today's volatile nitrogen fertilizer prices, which are often directly related to the price of natural gas ( Raun et al., 2002). When taking into account the financially unstable world market and the fact that natural gas is a non-renewable resource that will eventually become more costly and difficult to extract, scientists should be encouraged to develop techniques to use less nitrogen fertilizer while maintaining current production levels.

Currently NUE is 33% for cereal grain production worldwide (Raun and Johnson, 1999); however, there are methodologies currently in practice that can greatly increase NUE. Some of these techniques include: rotations, forage production systems, genetically modified hybrids, foliar applied nitrogen, and precision agriculture approaches (application resolution) (Raun and Johnson et al., 1999). It is the responsibility of developed nations to implement these known practices to increase NUE, while exploring new techniques that integrate ever expanding technologies that may further our ability to precisely place nutrients such as nitrogen.

## CHAPTER II

### LITERATURE REVIEW

Applying midseason nitrogen in corn can often lead to increased NUE (Tubañá et al., 2008). In opposition to midseason application, applying all nitrogen pre-plant or fall applied has in recent years been considered as less desirable (Buzicky, 1983). Buzicky (1983) found that when nitrogen was fall applied, nitrogen losses were 36 percent greater than nitrogen that was applied in the spring (closer to midseason).

It has been shown that corn only takes up about 1 lb of nitrogen per acre by the four leaf stage. Furthermore, corn does not often start accumulating substantial amounts of nitrogen until approximately forty days after emergence (Sawyer et al., 2006). Additionally, the natural soil environment has the ability to supply these low levels of nitrogen in the early physiological development through mineralization and decomposition of organic remnants (Mary et al., 2004). Nitrogen applied before corn can fully utilize it is considered risky at best; nitrogen is susceptible to loss by several mechanisms such as plant loss as ammonia ( $\text{NH}_3$ ), denitrification, surface runoff, leaching and volatilization (Raun and Johnson, 1999).

While midseason application (V8 to V10) can greatly increase NUE (Tubaña et al., 2008) there is some thought in the agricultural community that midseason application can limit uptake because of subsequent timing issues (Randall and Iragavarapu, 1998). There are two forms of plant available nitrogen, ammonium ( $\text{NH}_4^+$ ) and nitrate ( $\text{NO}_3^-$ ). Nitrate is mobile within the soil and is highly affected by increasing and decreasing moisture as well as temperature regimes (Lamb et al., 2008). Furthermore, nitrate is the most mobile and moves by two specific mechanisms in the soil, mass flow and diffusion of which mass-flow accounts for approximately 80% of plant uptake (Ballance, 2009). Factors that increase nitrogen movement and subsequent mobility in the soil are high moisture regimes and high diffusion potentials (NaNagara et al., 1975).

The controversy arises in the upper Midwest where growing seasons and application windows are much shorter allowing less opportunity for midseason application (Randall and Iragavarapu, 1998). These midseason applications (V8 to V10) are only of concern when there aren't substantial rainfall events after midseason application to initiate substantial nitrate movement by mechanisms of mass-flow. Furthermore, these subsequently low moisture regimes could also hinder nitrogen movement in arid to semi arid regions in such areas as the southern Great Plains where success or failure of corn production is highly dependent on timely precipitation events. In a study conducted at Oklahoma State University, midseason applications (V-8 to V-10) of nitrogen were applied to every other row. Rows that did not have midseason applications had lower yield levels and did not benefit from midseason applications of the adjacent row (Edmonds, 2007). This study provides evidence that mass flow of

nitrate in semi-arid to arid climates may not be substantial enough to move midseason N great distances in a single growing season on a micro-scale (0 to 76 cm).

Midseason applications of nitrogen fertilizers in corn have proven to be a challenge in the past due to troublesome weather conditions and limited application windows (Rehm, 2006). However, with the recent advent of technologies such as real time kinematics (RTK automatic guidance systems), larger application equipment, and the ability to make quick and accurate in season nitrogen recommendations using optical sensors such as the GreenSeeker<sup>TM</sup> developed at Oklahoma State University, have enabled producers and agronomists to hit these limited application windows with placement accuracies on the sub inch scale.

The sub inch scale has been an important area of research in recent years, and there have been several studies conducted when applying nitrogen pre-plant (shortly before planting). Vyn and West, (2008) from the University of Purdue found that planting corn using RTK guidance systems five inches from the pre-plant band of UAN generally improved corn grain yields (Vyn and West, 2008). It was also evident that all corn planted directly over the four inch deep band had a higher nitrogen concentration, however yielded lower in most cases probably due to yield reductions that were a result of seed to fertilizer contact or poor seed bed preparation from recent nitrogen applications (Vyn and West, 2008).

Additionally other studies have concluded that moisture regimes have a demanding effect on the benefits of planting variable distances from pre-plant nitrogen bands (Shoup and Janssen, 2009). Extremely wet conditions during early physiological

development of corn may decrease vigorous root formations so planting closer to nitrogen bands may be beneficial in this situation (Shoup and Janssen, 2009).

Alternatively planting closer to pre-plant nitrogen bands in normal to dry conditions in the same geographic region proved to have little to no beneficial effect on corn grain yield.

Placement, timing, variable soil and weather conditions all have demanding effects on optimal placement of nitrogen fertilizers during both pre-plant and midseason applications. Judging by the complexity of the interactions that take place within the soil environment it would be advisable to continue research regarding placement, especially since research on these types of nitrogen placement studies are in their relative infancy, due to recent advances in guidance and application methodologies. This research would help to further the quest to improve NUE while increasing yields, maintaining environmental stewardship, and lowering production costs.

## Chapter III

### OBJECTIVE

The objectives of this research was to evaluate midseason (V8 to V10) liquid UAN (28%) rates (45, 90, 134, and 224 kg N ha<sup>-1</sup>) applied at different distances (0, 10, 20, 30 and 38 cm) within the row on corn grain yields. Furthermore, applying UAN directly to the plant stalks (13 cm) vertically from the soil surface along a horizontal plane will also be evaluated as a function of corn grain yield response.

## Chapter IV

### MATERIALS AND METHODS

Experimental sites were established at the R.L. Westerman Irrigation Research Station near Stillwater, OK in the spring of 2008 and 2009. In the spring of 2009, one more site location was added near Haskell, OK (dry-land). The established site at the R.L. Westerman Irrigation Research Station is located on a Port-Oscar silt loam (fine-silty, mixed, super active, thermic Cumulic Haplustolls), and the site near Haskell, OK (dry-land) is located on a Taloka silt loam (Fine, mixed, active, thermic Mollic Albaqualfs). Each site was planted to corn (*Zea mays* L.). The irrigated site was planted at a population of 81,510 seeds ha<sup>-1</sup> (Pioneer 33B-54) in 2008 and 113,620 seeds ha<sup>-1</sup> (DKC68-06) in 2009, while the 2009 dry-land site was planted at a population of 66,690 (DKC52-59) seeds ha<sup>-1</sup>. Each site was planted into a corn on corn rotation using conventional tillage methodologies. All site years were planted with a row spacing of 76 cm, with a John Deere Maxemerge 2, four row vacuum planter. A composite soil sample was taken at all site years and locations before planting soil nutrient analysis is reported in Table 1. The established trials in all site years and locations used a completely



randomized block design consisting of three replications with plots that were 20 meters long by four rows wide (76 cm row spacing). Additionally, at all site years and locations, treatments 6 through 17 received a pre-plant treatment of liquid UAN (28%) at 45 kg N ha<sup>-1</sup>. The remaining treatments for the 2008, R.L. Westerman Irrigated site and the 2009 Haskell dry-land site years and location were applied midseason (V-8 to V-10) to the soil surface in a continuous stream at rates of 45, 90, and 134 kg N ha<sup>-1</sup> at variable distances of 0, 10, 20, and 30 cm from the plant.

During the second season, 2009, additional treatments were added at the R.L. Westerman Irrigated site, to determine the potential vegetative tissue burning effects and possible grain yield losses associated with applying a high midseason (V8 to V10) rate of UAN (28%), (224 kg N ha<sup>-1</sup>) at variable distances from the plant and locations on the plant. Treatment 18 was placed at (0 cm) the base of the plant (Figure 1.), treatment 19 was placed 13 cm vertically from the soil surface along a horizontal plane directly to the plants stalks (Figure 2.), and treatment 20 was placed (38 cm) down the center of the row (Figure 3.) to the soil surface, replicating a more traditional midseason nitrogen application approach. These additional treatments (18, 19, and 20) did not receive a UAN (28%) pre-plant rate. Treatment structures for 2008 and 2009 are reported (Table 2. 2008 irrigated, Table 3. 2009 irrigated, and Table 4. 2009 dry-land treatment structures).

At harvest, the two middle rows of each plot were harvested using a Massey Ferguson 8XP experimental plot combine, equipped with a HarvestMaster automated weighing system (HarvestMaster Inc. , 1994) to collect individual plot weights. Plot

weights were calculated by taking the wet weight minus the dry weight and dividing by the wet weight. Grain yields for all treatments were expressed using 15.5% moisture and were later converted to yield in  $\text{kg ha}^{-1}$ . Analysis of variance to determine treatment effects was determined using SAS (SAS Inc, 2003). Significant differences between treatments were evaluated using the standard error of the difference (SED) between two equally replicated means. Furthermore, non-orthogonal single-degree-of-freedom contrasts were performed to further evaluate treatment effects.

# CHAPTER V

## RESULTS

### **R.L. Westerman Irrigated Research Station, 2008**

When evaluating corn grain yields using analysis of variance (SAS, 2003) for the R.L. Westerman 2008 Irrigated Research Station, it was found that N rate ( $Pr > F$ , 0.0001), application distance ( $Pr > F$ , 0.0001), and the interaction between N rate and application distance ( $Pr > F$ , 0.0011) (Table 5.), were all significant at the 0.05 significance level. Because of this the main effects of N rate and application distance could not be evaluated separately. The interaction means of N rate \* application distance were thus plotted in Figure 4. Applying N directly to the base of the plant (0 cm) resulted in equal or better yields when compared to 20 and 30 cm application distances.

### **45 kg ha<sup>-1</sup> Midseason Application** (Rate 45 kg N ha<sup>-1</sup>)

The 0 cm application distance had the highest mean grain yield (6990 kg ha<sup>-1</sup>) followed by the 20 cm (6482 kg ha<sup>-1</sup>) and then the 10 cm (5412 kg ha<sup>-1</sup>) application

distances, while the 30 cm ( $4011 \text{ kg ha}^{-1}$ ) application distance had the lowest grain yields at the  $45 \text{ kg ha}^{-1}$  midseason N rate. The resulting contrast showed that placing midseason N ( $45 \text{ kg}$ ) at a distance of 0 cm was significantly superior to placing midseason N at the 10, or 30 cm application distances. Contrasts are reported in Table 6.

**45 kg N ha<sup>-1</sup> Pre-plant + 45 kg N ha<sup>-1</sup> Midseason Application** (Total N-rate  $90 \text{ kg N ha}^{-1}$ )

The 0-cm application distance resulted in the highest mean grain yields ( $9184 \text{ kg ha}^{-1}$ ) followed by 20-cm, ( $7872 \text{ kg ha}^{-1}$ ) and 30-cm ( $7756 \text{ kg ha}^{-1}$ ) application distances with the 10-cm ( $6405 \text{ kg ha}^{-1}$ ) application distance having the lowest mean grain yield. The resulting contrast showed that placing midseason applications ( $45 \text{ kg N ha}^{-1}$ ) at a distance of 0-cm was significantly superior to placing midseason applications at the 10, 20, and-30 cm application distances. Contrasts are reported in Table 6.

**45 kg N ha<sup>-1</sup> Pre-plant + 90 kg N ha<sup>-1</sup> Midseason Application** (total N-rate  $134 \text{ kg N ha}^{-1}$ )

The 10-cm midseason application distance resulted in the highest mean grain yield ( $9685 \text{ kg ha}^{-1}$ ), followed by the 0-cm midseason application distance ( $9227 \text{ kg/ha}^{-1}$ ); while the 20, ( $8891 \text{ kg/ha}^{-1}$ ) and 30-cm ( $7937 \text{ kg/ha}^{-1}$ ) midseason applications resulted in lower mean grain yields. The contrasts revealed that placing a midseason application at 0-cm at a rate of  $90 \text{ kg N ha}^{-1}$  was not significantly different than placing midseason applications at 10, 20, or 30-cm. However, placing midseason N at a distance of 10 cm

was statistically superior to applying midseason N at the 30-cm application distance.

Contrasts are reported in Table 6.

**45 kg N ha<sup>-1</sup> Pre-plant + 134 kg N ha<sup>-1</sup> Midseason Application** (total N-rate 179 kg N ha<sup>-1</sup>)

The 0-cm application distance had the highest mean grain yield (10619 kg ha<sup>-1</sup>) followed by the 10 (9771 kg ha<sup>-1</sup>), 20 (7961 kg ha<sup>-1</sup>) and 30 cm (7627 kg ha<sup>-1</sup>) midseason application distances. The contrast showed that placing midseason N (134 kg N ha<sup>-1</sup>) at a distance of 0-cm was better than placing midseason N at the 20 or 30-cm application distances. Furthermore contrasts also suggested that the 10-cm midseason application was better than the 20 and 30-cm midseason application distances. Contrast are reported in Table 6.

### **R.L. Westerman Irrigated Research Station, 2009**

When evaluating corn grain yields using analysis of variance (SAS, 2003) for the R.L. Westerman 2009 Irrigated Research Station, it was found that N rate (Pr > F, 0.004) was significant at the 0.05 significance level. Application distance (Pr > F, 0.23) and the interaction between N rate and application distance (Pr > F, 0.68) (Table 6.) were not significant. The interaction means of N rate \* application distance were plotted and are reported in Figure 5. Even though the interaction means for N rate\* application distance were not significant at the 0.05 significance level, the 0-cm application distance produced slightly higher mean grain yields for the 90 and 134 kg N ha<sup>-1</sup> midseason application distance when comparing them to the 10, 20, and 30-cm application distances.

#### **45 kg N ha<sup>-1</sup> Midseason Application** (total N-rate 45 kg N ha<sup>-1</sup>)

The 10-cm application distance had the highest mean grain yield (13908 kg ha<sup>-1</sup>) followed by 0-cm (13429 kg ha<sup>-1</sup>) and the 30-cm (13670 kg ha<sup>-1</sup>) application distances, while the 20-cm (10961 kg ha<sup>-1</sup>) application distance had the lowest mean grain yields at the 45 kg ha<sup>-1</sup> midseason N rate. The resulting contrast showed that placing midseason N (45 kg ha<sup>-1</sup>) at a distance of 0-cm was not significantly better than placing midseason N at the 10, 20, or 30-cm application distances (Table 8).

#### **45 kg N ha<sup>-1</sup> Pre-plant + 45 kg N ha<sup>-1</sup> Midseason Application** (total N-rate 90 kg N ha<sup>-1</sup>)

The 0-cm (13146 kg ha<sup>-1</sup>) application distance resulted in the highest mean grain yields followed by the 20, (10864 kg ha<sup>-1</sup>) and 10 cm (9935 kg ha<sup>-1</sup>) application distances with the 30 cm (9496 kg ha<sup>-1</sup>) application distance having the lowest mean grain yield. The resulting contrasts showed that placing midseason N (45 kg N ha<sup>-1</sup>) at a distance of 0-cm was better than placing N at the 30-cm distance. However, was not significantly better than placing midseason N at the 10 or 20 cm application distance (Table 8).

#### **45 kg/ha<sup>-1</sup> Pre-plant + 90 kg/ha<sup>-1</sup> Midseason Application** (total N-rate 134 kg/ha<sup>-1</sup>)

The 0-cm midseason N application distance resulted in the highest mean grain yield (14673 kg/ha<sup>-1</sup>), followed by the 30-cm midseason N application (14287 kg/ha<sup>-1</sup>). The 10 (14212 kg/ha<sup>-1</sup>) and 20-cm (11138 kg/ha<sup>-1</sup>) midseason applications resulted in the lowest mean grain yields. Contrasts revealed that placing midseason N at 0-cm at a rate

of 90 kg N ha<sup>-1</sup> was not significantly different than placing midseason N at the 10, 20, or 30-cm application distances (Table 8).

**45 kg N ha<sup>-1</sup> Pre-plant + 134 kg N ha<sup>-1</sup> Midseason Application** (total N-rate 179 kg N ha<sup>-1</sup>)

The 10-cm application distance had the highest mean grain yield (16822 kg ha<sup>-1</sup>) followed by the 30, (16640 kg ha<sup>-1</sup>) 20, (15562 kg ha<sup>-1</sup>) and 0-cm (15123 kg ha<sup>-1</sup>) midseason application distances. Contrasts revealed that placing midseason N (134 kg N ha<sup>-1</sup>) at a distance of 0-cm was not significantly better than placing midseason N at the 10, 20, or 30-cm application distances (Table 8).

**R.L. Westerman Irrigated Research Station, High N Rate Treatments, 2009**

(total N-rate 224 kg N ha<sup>-1</sup>)

When evaluating corn grain yields using analysis of variance (SAS, 2003) for the high rate treatments, it was found that application placement ( $Pr > F$ , 0.085) was not significant at the 0.05 significance level (Table 9). Mean grain yields for the application placement were graphed and are reported in Figure 6. Even though means for the high rate were not significant at the 0.05 significance level, the 0-cm application placement (at the base plant) resulted in higher mean grain yields than placing midseason N on the stalks (13 cm vertically from the soil surface along a horizontal plane) or down the middle of the row (38 cm). Furthermore, the resulting contrasts showed that placing midseason N (224 kg N ha<sup>-1</sup>) at a distance of 0 cm (at the base plant) was significantly better than placing midseason N on the plant stalks (13 cm vertically from the soil surface along a horizontal plane)(Table 10). Additionally, physical burning was visually

evaluated on all the high rate treatments (13 cm vertically from the soil surface along a horizontal plane, 0-cm at the base plant, and 38 cm from the plant or middle of the row) Visual evaluation noted slight burning at the 0 cm application distance (at the base); however this did not detrimentally affect grain yields. Visual observations are included in Figure 7, application in the center of the row (38 cm) and Figure 8 illustrating application at the base of the plant (0 cm).

### **Haskell, OK Dry-land Location 2008**

The Haskell OK, dry-land site experienced extremely low corn grain yields due to only 4.38 cm of precipitation from emergence to blister (VE to R2). Furthermore, the Haskell, OK region experienced very hot conditions with temperatures reaching into the 100 degree range for a period of six days during the initiation of tasseling. Grain yields were further depressed due to extremely poor weed management by the experiment station, coupled by the fact that the experiment was unknowingly placed over a long term wheat fertility experiment. Soil samples revealed that the portion of the trial that was placed over the long term experiment had a soil pH of 4.5. Soil sample data is reported in Table 1.

These yield reductions resulted in nine plots having no harvestable corn grain yields. The means of the grain yields from the harvestable treatments were 4147 kg/ha<sup>1</sup>, with the check plots (treatment 1) that received no added N having a mean grain yield of 4679 kg/ha<sup>-1</sup>. The resulting low and absent corn grain yields resulted in the inability of means to be calculated for treatments 11 and 12. With the low nitrogen response



due to yield depression and the presence of missing data, this data set was not used to evaluate N rate, application distance or the interaction between N rate\* application distance.

# CHAPTER VI

## DISCUSSION

The data presented in this research suggest that placing midseason application of UAN closer to the plant can substantially increase corn grain yields. This was observed through visual observations (Figures 7, and 8.), as well as through the resulting corn grain yields. Mengel and Barber (1974) noted that corn root mass was perhaps greatest in the soil surface (0-15 cm) and located directly under the plant. They also observed that as distance from the planted row increased, root densities substantially decreased (Mengel and Barber, 1974). With this gained knowledge coupled with the fact that it is possible to apply relatively high concentrations of N midseason, directly to the base of the plant, it would not be wise to continue placing midseason applications in the center of a 76 cm row, where midseason application can be lost or not fully utilized by corn roots.

Hodgen et al. (2009) found that when applying midseason (V-12)  $^{15}\text{N}$  directly under a single corn plant, 63 percent of the  $^{15}\text{N}$  applied was assimilated by that specific plant within a 0.18 m horizontal radius (Hodgen et al., 2009). Hodgen et al. (2009) also

noted that if the target plant was supplied with sufficient  $^{15}\text{N}$ , neighboring plants 0.18 m away contained less of that  $^{15}\text{N}$  than the one that was targeted. Plants that were 0.36 m away contained even lower amounts of that  $^{15}\text{N}$  supplied to the target plant (Hodgen et al., 2009). This phenomenon was also noted with findings by Blaylock and Cruise (1992), where midseason N was broadcast, point injected in the center of the row, and point injected into a ridge-till mound approximately 50 mm from the planted row. Results were variable; however, it was noted in some conditions there may be substantial benefit to closer placement of midseason N application. This was not always the case over all eight years. This data, as well as data presented in this research seems to support the idea of closer midseason N applications (Blaylock and Cruise, 1992).

Further research is still needed; however, this data suggests that if midseason applications are placed closer to the plant (0, and 10 cm) producers may be able to obtain higher grain yields with lower amounts of N fertilizer, evident in Figures 4 and 5.

The evaluation of midseason N placement in dry-land conditions was not possible due to the extremely low yield levels achieved. However, other data suggests that soil moisture regimes may not be substantial enough in the southern Great Plains under dry-land conditions to move midseason N great distances within a single growing season (76 cm) (Edmonds, 2007). This research becomes increasingly important if corn acres dramatically increase in regions like the southern Great Plains, which is now considered a marginal corn production area due to sometimes extensive periods without rain in the summer months. If drought tolerant hybrids are developed this could change the way corn production is viewed in these areas. Furthermore,

midseason applications and placement could become increasingly important if corn acres increase in these regions, allowing producers and agronomist to make decisions on added midseason applications depending on expected yield goals (related to in season soil moisture) within that growing season.

## CHAPTER VII

### CONCLUSIONS

The data presented in this paper suggests that when applying UAN to the soil surface using conventional tillage methods under irrigated conditions it is beneficial to corn grain yields to apply midseason N closer to the planted row. Substantial benefits were seen when midseason applications were placed at the base of the plant (0-cm) and the 10 cm application distances; however, it is not fully understood why the 10 cm application distance only produced higher corn grain yields at the two highest midseason application rates ( 134 and 179 kg N ha<sup>-1</sup> ). Furthermore, it should be understood that these results are probably highly dependent on soil texture and could be further affected by such factors as variable soil bulk densities (anthropogenic).

With the recent technological advances in automatic guidance it is now possible to accurately and precisely place nutrients on a scale only once imagined. This technology opens the doors for research that was once deemed impractical. The

encouraging data presented in this paper should serve as a catalyst for this future research.

## BIBLIOGRAPHY

- Ballance. 2009. Nitrogen and plants [Online]. from Fertilizers and plants:  
([http://www.ballance.co.nz/Education/Fertilisers\\_and\\_Plants/Nitrogen\\_and\\_plants.asp?PaPage=4142&ID=9&CatID=2057&Level=](http://www.ballance.co.nz/Education/Fertilisers_and_Plants/Nitrogen_and_plants.asp?PaPage=4142&ID=9&CatID=2057&Level=)). (verified 17 May. 2009).
- Blaylock, A.D., and R.M. Cruse. 1992. Ridge-tillage corn response to point injected nitrogen fertilizer. *Soil Sci. Soc. Am. J.* 56:591–595.
- Buzicky, G. C., 1983. Fertilizer N losses from a tile-drained mollisol as influenced by rate and time of 15 N depleted fertilizer applications. p. 213. In 1983 Agronomy abstracts. ASA, Madison, WI.
- Booth, M. 2009. Dead in the Water [Online]. from EWG Research:  
(<http://www.ewg.org/reports/deadzone>). (verified 13 May. 2009).
- Edmonds, D.E. 2007. Corn Grain Yield Response to Variable Row Nitrogen Fertilizer. M.S. thesis. Oklahoma State Univ.
- HarvestMaster Inc. 1994. HM-1/HM-2 Field Book: Users Manual., Logan UT.
- Lamb, J., G. Randall, G. Rehm, and C. Rosen. 2008. Best Management Practices for Nitrogen use in Minnesota. St. Paul: University of Minnesota Extension.
- Leco Corporation. 2008. True Spec Series. Leco Corporations, St. Joseph, MI.
- Malakoff, David. 1998. Death by suffocation in the Gulf of Mexico. *Science* 281:190-192.
- Mary, B., S. Recous, D. Darwis, and D. Robin. 2004. Interactions between decomposition of plant residues and nitrogen cycling in soil. *Plant and Soil*. 181:71-82.
- Mengel, D.B., and S.A. Barber. 1974. Development and distribution of the corn root system under field conditions. *Agron. J.* 66:341–344.
- Microsoft Corporation. 2007. Microsoft Excel 2007. Microsoft, Redmond, WA.

- NaNagara, T., R. E. Phillips and J. E. Leggett. 1975. Diffusion and Mass Flow of Nitrate-Nitrogen into Corn Roots Grown Under Field Conditions. *Agron J.* 68:67-72.
- Hodgen, P.J., Ferguson, R.B., Shanahan, J.F., Schepers, J.S. 2009. Uptake of Point Source Depleted  $^{15}\text{N}$  Fertilizer by Neighboring Corn Plants. *Agron J.* 101: 99-105.
- Randall, G. M. and T.K. Iragavarapu. 1998. Advisability of fall-applying nitrogen . *Wisconsin fertilizer, Aglime and Pest Management Conference*. Middleton, WI.
- Raun, W.R., and G.V. Johnson. 1999. Improving Nitrogen Use Efficiency for Cereal Production. *Agron. J.* 91:357-363.
- Raun, W.R., J. S. Solie, G.V. Johnson, M.L. Stone, R.W. Mullen, K.W. Freeman, W.E. Thomason, and E.V. Lukina 2002. Improving Nitrogen Use Efficiency in Cereal Grain Production with Optical Sensing and Variable Rate Application . *Agron. J.* 94:815-820.
- Rehm, G. 2006. Factors That Affect Suggested Fertilizer Nitrogen Rates. Concepts and Rationale for Regional Nitrogen Rate Guidelines for Corn. Ext Pub, PM 2015. Iowa State University Extension., Iowa City, IA.
- SAS Institute. 2003. SAS/STAT User's Guide: Release 9.1 ed. SAS Inst., Cary, NC.
- Sawyer, J., E. Nafziger, G. Randall, L. Bundy, G. Rehm, and B. Joern. 2006. Concepts and Rationale for Regional Nitrogen Rate Guidelines for Corn. Iowa City: Iowa State University.
- Schepers, J.S., D.D. Francis, and M.T. Thompson. 1989. Simultaneous determination of total C, total N and  $^{15}\text{N}$  on soil and plant material. *Commun. Soil Sci. Plant Anal.* 20:949-959.
- Shoup, D., K. Janssen. 2009. Diagnosing uneven corn height problems. *Agronomy e-update* 191, Kansas State Ext Pub. Manhattan, KS.
- Solie, J. B., W. R. Raun, and M. L. Stone. 1999. Submeter Spatial Variability of Selected Soil and Plant Variables. *Soil Sci. Soc. Am. J.* 63:1724-1733.
- Tubaña, B. S., D. B. Arnall, O. Walsh, B. Chung, J. B. Solie, and K. Girma. 2008. Adjusting Midseason Nitrogen Rate Using a Sensor-Based Optimization Algorithm to Increase Use Efficiency in Corn. *J. Plant Nutrition.* 31:8, 1393 - 1419.
- United Nations. 2005. World population to reach 9.1 billion in 2050 [Online] UN projects. United Nations Press. New York, NY.



(<http://www.unis.unvienna.org/unis/pressrels/2005/unisinf88.html>) (verified 29 Oct. 2009).

United States Geological Survey. 2008. Toxic Substances Hydrology Program. [Online]. (<http://toxics.usgs.gov/definitions/eutrophication.html>). (verified 29 Aug. 2009).

Vyn, T.J., and T.D. West. 2008. Efficient fluid fertilizer management for corn producers with automatic guidance systems. Year 3 Results. Fluid Forum Proceedings CD Volume 26, Fluid Fertilizer Foundation.

**Table 1: Soil surface (0-15 cm) nutrient analysis prior to trial implementation all site years and locations, NH<sub>4</sub>-N and NO<sub>3</sub>-N – 2 M KCL extract; P and K – Mehlich-3 extraction; pH – 1:1 soil: deionized water.**

<b>Experiment Location</b>	<b>Sample Depth (cm)</b>	<b>Potassium (mg kg<sup>-1</sup>)</b>	<b>Phosphorus (mg kg<sup>-1</sup>)</b>	<b>NH<sub>4</sub>-N (kg/ha)</b>	<b>NO<sub>3</sub>-N (kg/ha)</b>	<b>pH</b>
<b>R.L. West Irrigated, 08</b>	0-15	248	37	9	8	6.0
<b>R.L. West Irrigated, 09</b>	0-15	138	22.2	0	1	5.9
<b>Haskell OK, Dry-la, 09</b>	0-15	74.5	32	0	29	4.6

Figure 1: Graphical representation of treatment 18's application methodology which was placed (0 cm) along the base of the plant, R.L. Westerman 2009 high rate Irrigated Research Station, near Stillwater OK.

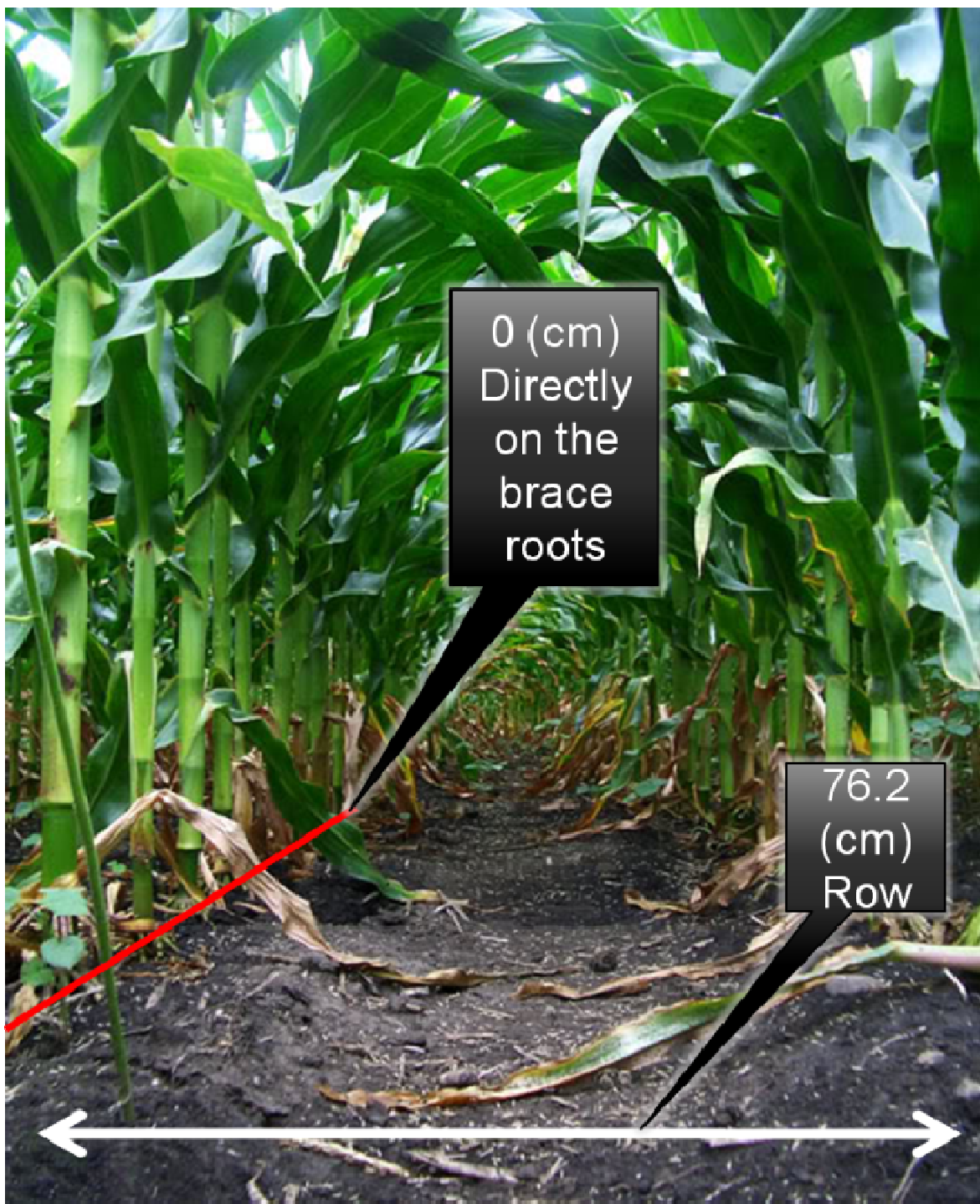
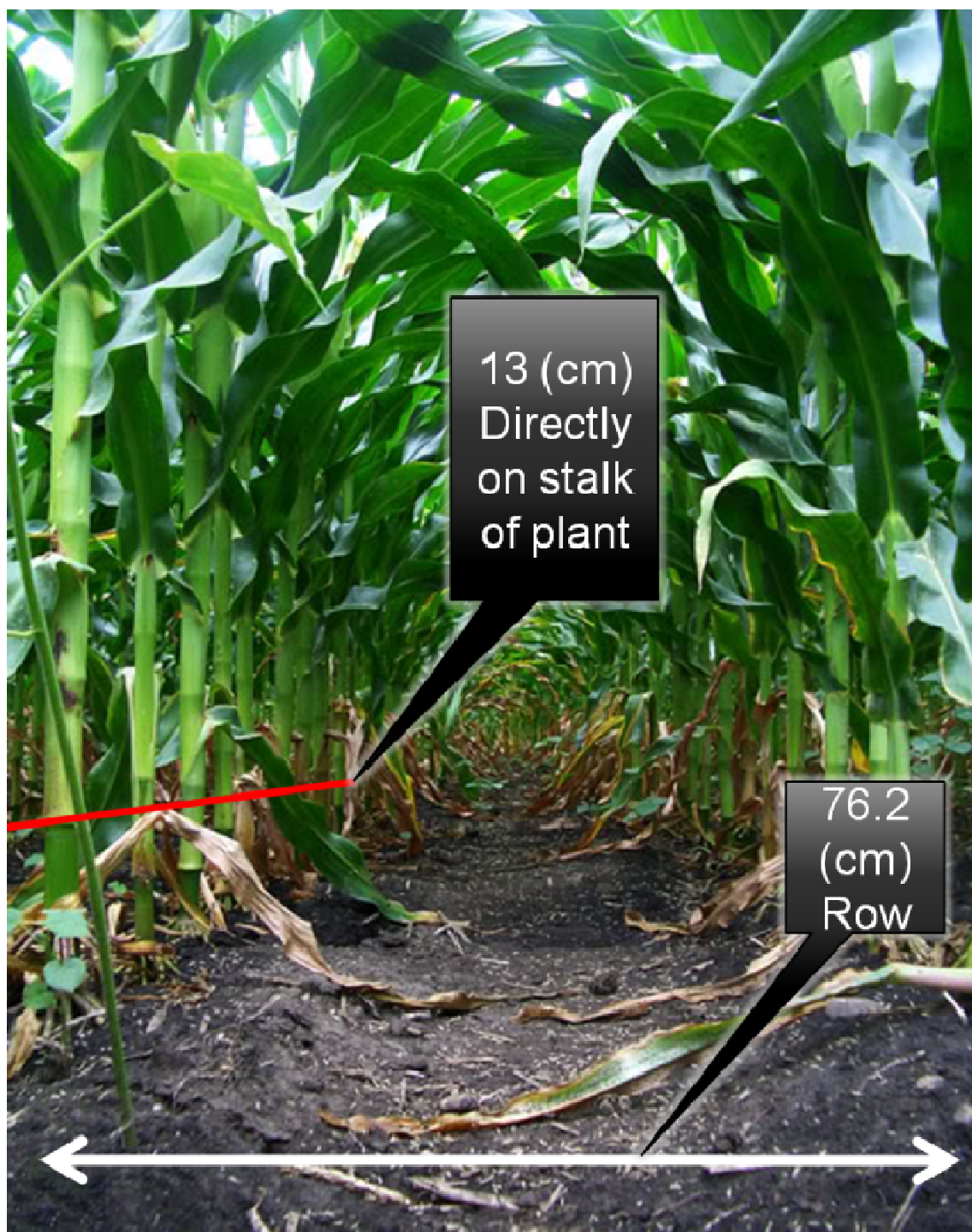
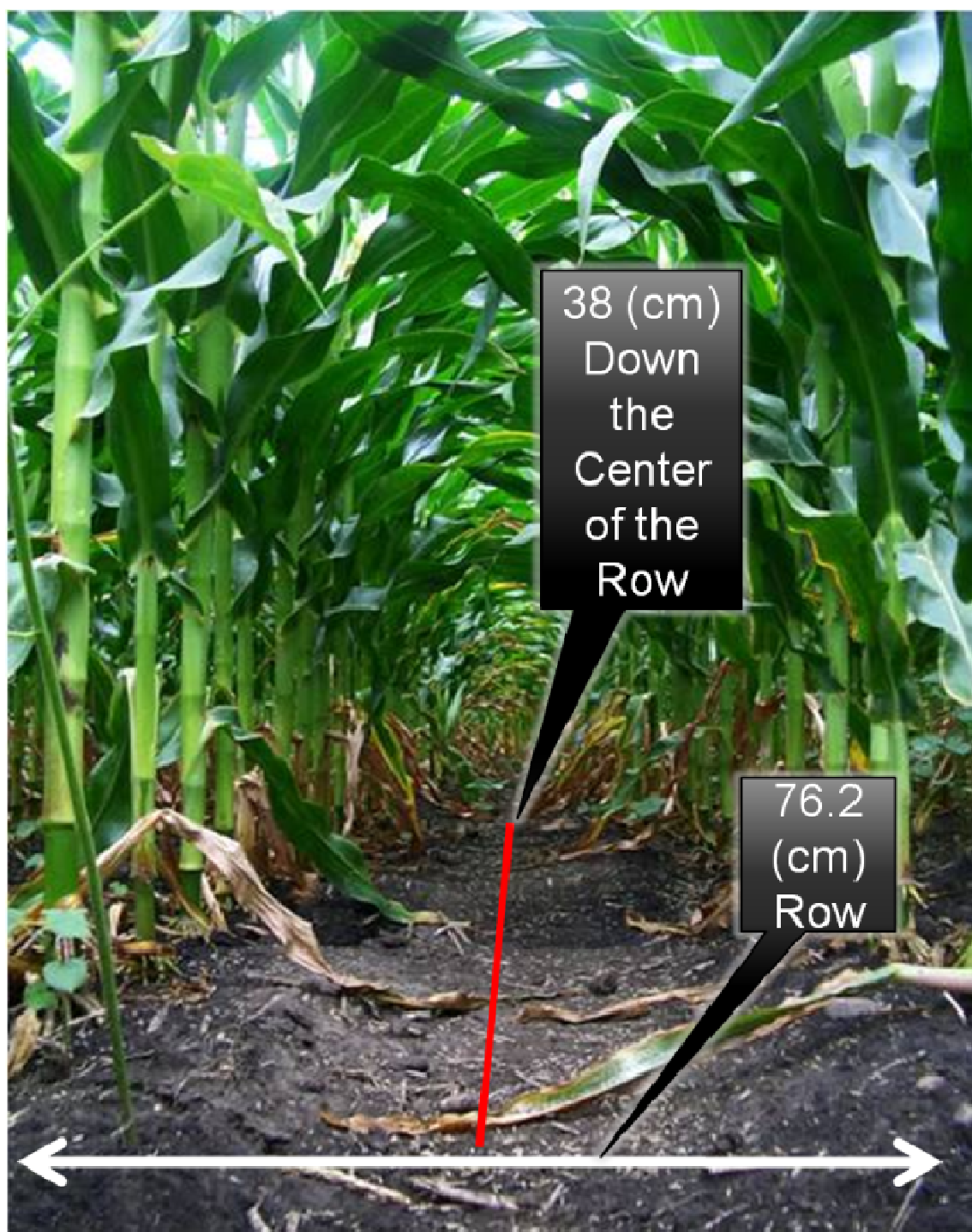


Figure 2: Pictorial representation of treatment 19's application methodology (13 cm) placed vertically from the soil surface along a horizontal plane directly to the plants stalk, R.L. Westerman 2009 high rate Irrigated Research Station, near, Stillwater OK



**Figure 3: Pictorial representation of treatment 20's application methodology placed directly down the center of the row (38 cm), R.L. Westerman 2009 high rate Irrigated Research Station, near, Stillwater OK**



**Table 2: 2008 R.L. Westerman Irrigated Treatment Structure**

<b>Treatment</b>	<b>Pre-Plant N( kg/ha)</b>	<b>Midseason N (kg/ha)</b>	<b>Application Distance (cm)</b>
<b>1</b>	<b>0</b>	<b>0</b>	<b>0</b>
<b>2</b>	<b>0</b>	<b>45</b>	<b>0</b>
<b>3</b>	<b>0</b>	<b>45</b>	<b>10</b>
<b>4</b>	<b>0</b>	<b>45</b>	<b>20</b>
<b>5</b>	<b>0</b>	<b>45</b>	<b>30</b>
<b>6</b>	<b>45</b>	<b>45</b>	<b>0</b>
<b>7</b>	<b>45</b>	<b>45</b>	<b>10</b>
<b>8</b>	<b>45</b>	<b>45</b>	<b>20</b>
<b>9</b>	<b>45</b>	<b>45</b>	<b>30</b>
<b>10</b>	<b>45</b>	<b>90</b>	<b>0</b>
<b>11</b>	<b>45</b>	<b>90</b>	<b>10</b>
<b>12</b>	<b>45</b>	<b>90</b>	<b>20</b>
<b>13</b>	<b>45</b>	<b>90</b>	<b>30</b>
<b>14</b>	<b>45</b>	<b>134</b>	<b>0</b>
<b>15</b>	<b>45</b>	<b>134</b>	<b>10</b>
<b>16</b>	<b>45</b>	<b>134</b>	<b>20</b>
<b>17</b>	<b>45</b>	<b>134</b>	<b>30</b>



**Table 3: 2009 R.L. Westerman Irrigated Treatment Structure**

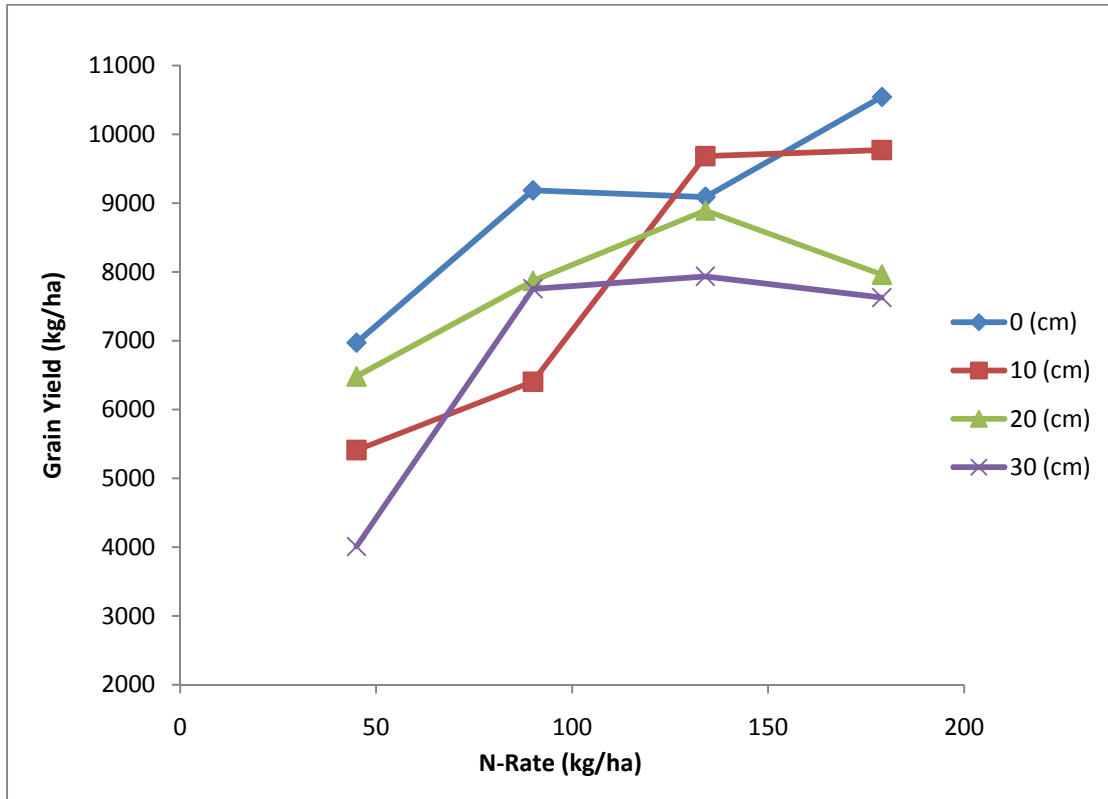
<b>Treatment</b>	<b>Pre-Plant N (kg/ha)</b>	<b>Midseason N (kg/ha)</b>	<b>Application Distance (cm)</b>
<b>1</b>	<b>0</b>	<b>0</b>	<b>0</b>
<b>2</b>	<b>0</b>	<b>45</b>	<b>0</b>
<b>3</b>	<b>0</b>	<b>45</b>	<b>10</b>
<b>4</b>	<b>0</b>	<b>45</b>	<b>20</b>
<b>5</b>	<b>0</b>	<b>45</b>	<b>30</b>
<b>6</b>	<b>45</b>	<b>45</b>	<b>0</b>
<b>7</b>	<b>45</b>	<b>45</b>	<b>10</b>
<b>8</b>	<b>45</b>	<b>45</b>	<b>20</b>
<b>9</b>	<b>45</b>	<b>45</b>	<b>30</b>
<b>10</b>	<b>45</b>	<b>90</b>	<b>0</b>
<b>11</b>	<b>45</b>	<b>90</b>	<b>10</b>
<b>12</b>	<b>45</b>	<b>90</b>	<b>20</b>
<b>13</b>	<b>45</b>	<b>90</b>	<b>30</b>
<b>14</b>	<b>45</b>	<b>134</b>	<b>0</b>
<b>15</b>	<b>45</b>	<b>134</b>	<b>10</b>
<b>16</b>	<b>45</b>	<b>134</b>	<b>20</b>
<b>17</b>	<b>45</b>	<b>134</b>	<b>30</b>
<b>18</b>	<b>0</b>	<b>224</b>	<b>0</b>
<b>19</b>	<b>0</b>	<b>224</b>	<b>13 on Stalks</b>
<b>20</b>	<b>0</b>	<b>224</b>	<b>38 Middle of the Row</b>

**Table 4: 2008 Haskell, OK Dry-land Treatment Structure**

<b>Treatment</b>	<b>Pre-Plant N( kg/ha)</b>	<b>Midseason N (kg/ha)</b>	<b>Application Distance (cm)</b>
<b>1</b>	<b>0</b>	<b>0</b>	<b>0</b>
<b>2</b>	<b>0</b>	<b>45</b>	<b>0</b>
<b>3</b>	<b>0</b>	<b>45</b>	<b>10</b>
<b>4</b>	<b>0</b>	<b>45</b>	<b>20</b>
<b>5</b>	<b>0</b>	<b>45</b>	<b>30</b>
<b>6</b>	<b>45</b>	<b>45</b>	<b>0</b>
<b>7</b>	<b>45</b>	<b>45</b>	<b>10</b>
<b>8</b>	<b>45</b>	<b>45</b>	<b>20</b>
<b>9</b>	<b>45</b>	<b>45</b>	<b>30</b>
<b>10</b>	<b>45</b>	<b>90</b>	<b>0</b>
<b>11</b>	<b>45</b>	<b>90</b>	<b>10</b>
<b>12</b>	<b>45</b>	<b>90</b>	<b>20</b>
<b>13</b>	<b>45</b>	<b>90</b>	<b>30</b>
<b>14</b>	<b>45</b>	<b>134</b>	<b>0</b>
<b>15</b>	<b>45</b>	<b>134</b>	<b>10</b>
<b>16</b>	<b>45</b>	<b>134</b>	<b>20</b>
<b>17</b>	<b>45</b>	<b>134</b>	<b>30</b>



**Figure 4: Corn grain yield means as influenced by the interaction between N-rate and application distance (distances away from the row), R.L. Westerman 2008 Irrigated Research Station, Stillwater, OK (SED = 623 kg/ha).**



**Table 5: Results of analysis of variance when evaluating N-rate, application distance, and the interaction between N-rate\*application distance on corn grain yields R.L. Westerman 2008 Irrigated Research Station, Stillwater, OK.**

Analysis of Variance	Degrees of Freedom	Mean Squares	Pr > F
Rep	2	208747	0.7018
N-rate	3	27648242	0.0001
Application Distance	3	8963128	0.0001
N-rate*Application Distance	9	2527135	0.0011
Error	30	582572	

**Table 6: Results of the Non-orthogonal single-degree-of-freedom contrasting used to compare the effects of the 0, 10, 20, and 30 cm application distances on corn grain yields within N-rate treatments and selected application distance treatments, R.L. Westerman 2008 Irrigated Research Station, Stillwater OK.**

<b>Total N-rate (kg/ha)</b>	<b>Contrast Application Distance (cm)</b>	<b>Contrast Treatments</b>	<b>Degrees of Freedom</b>	<b>Mean Squares</b>	<b>Pr &gt; F</b>
45	0 vs. 10	2 vs. 3	1	3651890	0.0173
45	0 vs. 20	2 vs. 4	1	360955	0.4359
45	0 vs. 30	2 vs. 5	1	13155944	0.0001
90	0 vs. 10	6 vs. 7	1	11578449	0.0001
90	0 vs. 20	6 vs. 8	1	2582083	0.0427
90	0 vs. 30	6 vs. 9	1	3054987	0.0284
134	0 vs. 10	10 vs. 11	1	531990	0.3453
134	0 vs. 20	10 vs. 12	1	58616	0.7526
134	0 vs. 30	10 vs. 13	1	1989829	0.0732
134	10 vs. 30	11 vs. 13	1	4579556	0.0084
134	20 vs. 30	12 vs. 13	1	1365403	0.1347
179	0 vs. 10	14 vs. 15	1	892735	0.2236
179	0 vs. 20	14 vs. 16	1	9996621	0.0002
179	0 vs. 30	14 vs. 17	1	12746532	0.0001
179	10 vs. 20	15 vs. 16	1	4914630	0.0065
179	10 vs. 30	15 vs. 17	1	6892629	0.0016

Figure 5: Corn grain yield means as influenced by nitrogen rate and application distance (distances away from the row), R.L. Westerman 2009 Irrigated Research Station, Stillwater, OK (SED = 1846 kg/ha).

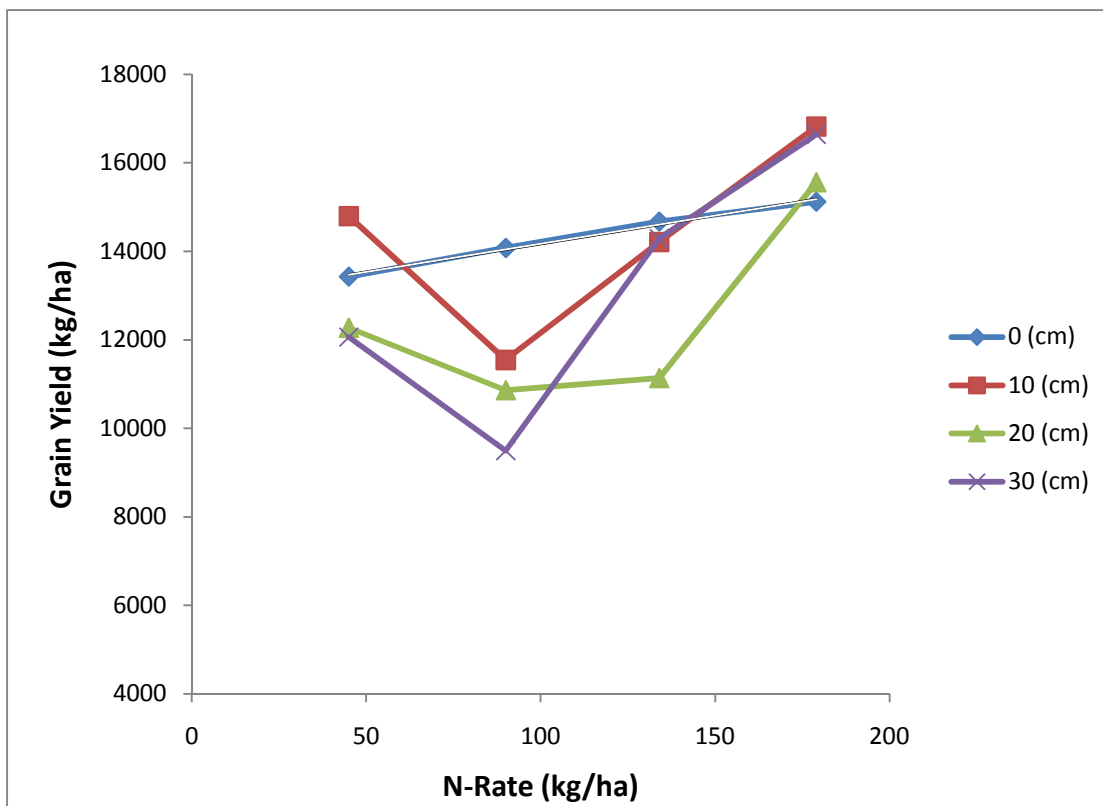


Table 7: Results of analysis of variance when evaluating N-rate, application distance, and the interaction between N- rate\*application distance on corn grain yields R.L. Westerman 2009 Irrigated Research Station, Stillwater, OK.

Source of Variation	Degrees of Freedom	Mean Squares	Pr > F
Rep	2	14562122	0.0736
N-rate	3	25565608	0.0038
Application Distance	4	7666392	0.2318
N-rate*Application Distance	9	3609101	0.6869
Error	25	5018372	

**Table 8: Results of the Non-orthogonal single-degree-of-freedom contrasting used to compare the effects of the 0, 10, 20, and 30 cm application distances within N-rate treatments and selected application distance treatments on corn grain yields, R.L. Westerman 2009 Irrigated Research Station, Stillwater OK.**

<b>Total N-rate (kg/ha)</b>	<b>Contrast Application Distance (cm)</b>	<b>Contrast Treatments</b>	<b>Degrees of Freedom</b>	<b>Mean Squares</b>	<b>Pr &gt; F</b>
45	0 vs. 10	2 vs. 3	1	288793	0.4147
45	0 vs. 20	2 vs. 4	1	2004662	0.4960
45	0 vs. 30	2 vs. 5	1	2813726	0.4206
90	0 vs. 10	6 vs. 7	1	9615263	0.1415
90	0 vs. 20	6 vs. 8	1	15489227	0.0648
90	0 vs. 30	6 vs. 9	1	22046375	0.0293
90	10 vs. 20	7 vs. 8	1	696868	0.6874
90	10 vs. 30	7 vs. 9	1	3758052	0.3529
90	20 vs. 30	8 vs. 9	1	1431393	0.5647
134	0 vs. 10	10 vs. 11	1	319656	0.7851
134	0 vs. 20	10 vs. 12	1	12650752	0.0935
134	0 vs. 30	10 vs. 13	1	43882	0.9195
134	0 vs. 20	12 vs. 13	1	9137804	0.1541
179	0 vs. 30	14 vs. 15	1	2677020	0.4320
179	10 vs. 20	14 vs. 16	1	192721	0.8323
179	10 vs. 30	14 vs. 17	1	2299798	0.4662

Figure 6: Corn grain yield means as influenced by application placement (0 cm at the base plant, 13 cm on the stalks, and 38 cm middle row ), R.L. Westerman 2009 high rate Irrigated Research Station, Stillwater, OK (SED = 208 kg/ha)

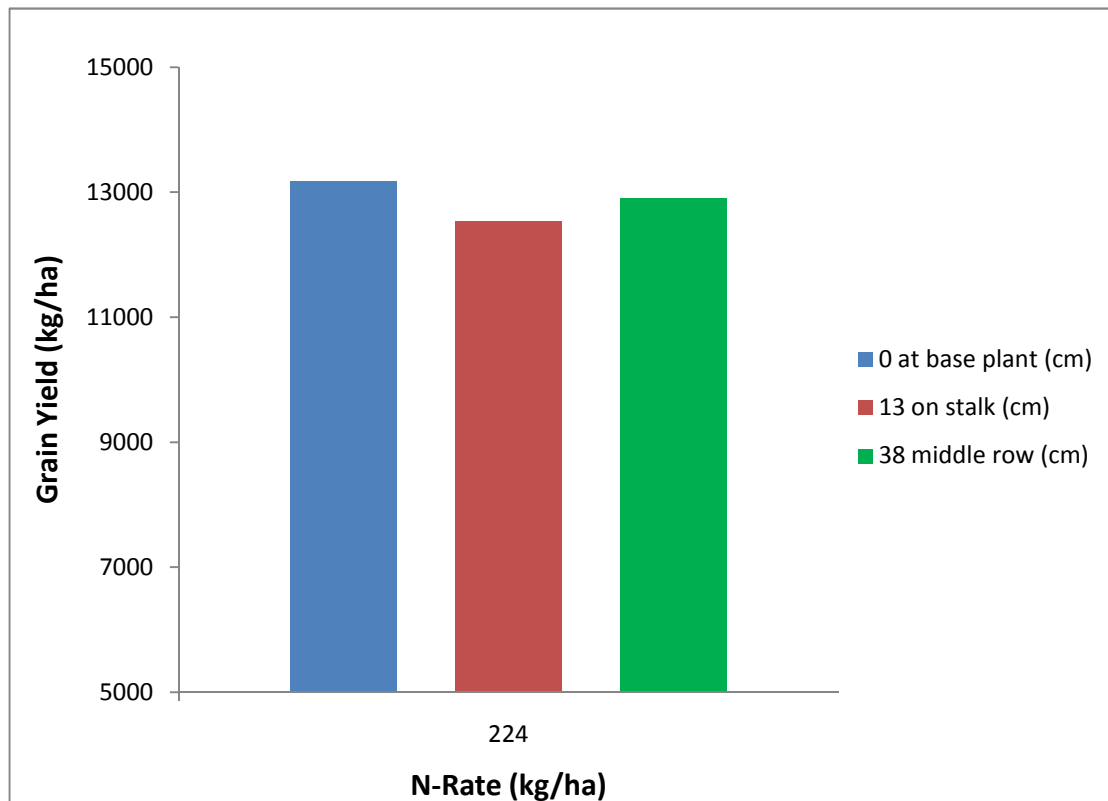


Table 9: Results of the analysis of variance when evaluating N placement, on corn grain yields R.L. Westerman 2009 high rate Irrigated Research Station. Stillwater, OK.

Source of Variation	Degrees of Freedom	Mean Squares	Pr > F
Rep	2	38152	0.5992
Application Location	2	315912	0.0857
Error	4	65363	

**Table 10: Results of non-orthogonal single-degree-of-freedom contrasts to compare the effects of placing midseason N on the plant stalks (13 cm vertically from the soil surface along a horizontal plane), or down the middle of the row (38 cm from the plant), vs., the 0 cm (at the base plant) application distance on corn grain yields, R.L. Westerman 2009 high rate Irrigated Research Station, Stillwater, OK.**

<b>Total N-rate (kg/ha)</b>	<b>Contrast Application Placement (cm)</b>	<b>Contrast Treatments</b>	<b>Degrees of Freedom</b>	<b>Mean Squares</b>	<b>Pr &gt; F</b>
224	0 vs. 13 on stalks	18 vs. 19	1	627560	0.0363
224	0 vs. 38 center of row	18 vs. 20	1	115290	0.2549

**Figure 7: Visual observation taken three days after 224 kg/ha midseason application at the 38 cm application distance (middle of the row), R.L. Westerman 2009 high rate Irrigated Research Station, Stillwater, OK.**



**Figure 8: Visual observation taken three days after 224 kg/ha midseason application at the 0 cm application distance, note very slight possible tissue burn, (circled in red) (at the base of the plant), R.L. Westerman 2009 high rate Irrigated Research Station, Stillwater, OK.**



## **APPENDIX**



**Figure 9: Economic N-Rate as related to application distance, (distance away from the row) R.L. Westerman 2008 and 2009 Irrigated Research Station, (Grain \$3.90 bu, Nitrogen \$0.42 /lbs) Stillwater OK.**

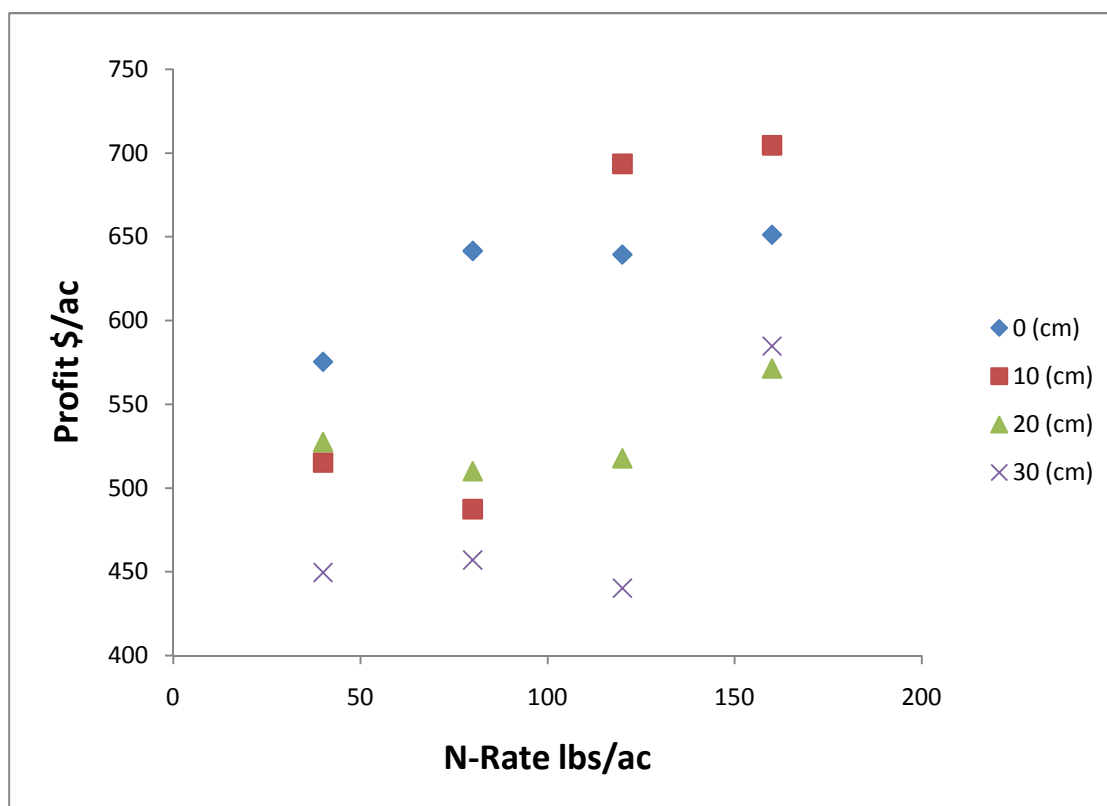


Figure 1: Corn grain yield means as influenced by the interaction between N-rate and application distance (distances away from the row), R.L. Westerman 2008 and 2009 Irrigated Research Station, Stillwater, OK (SED = 2986 kg/ha).

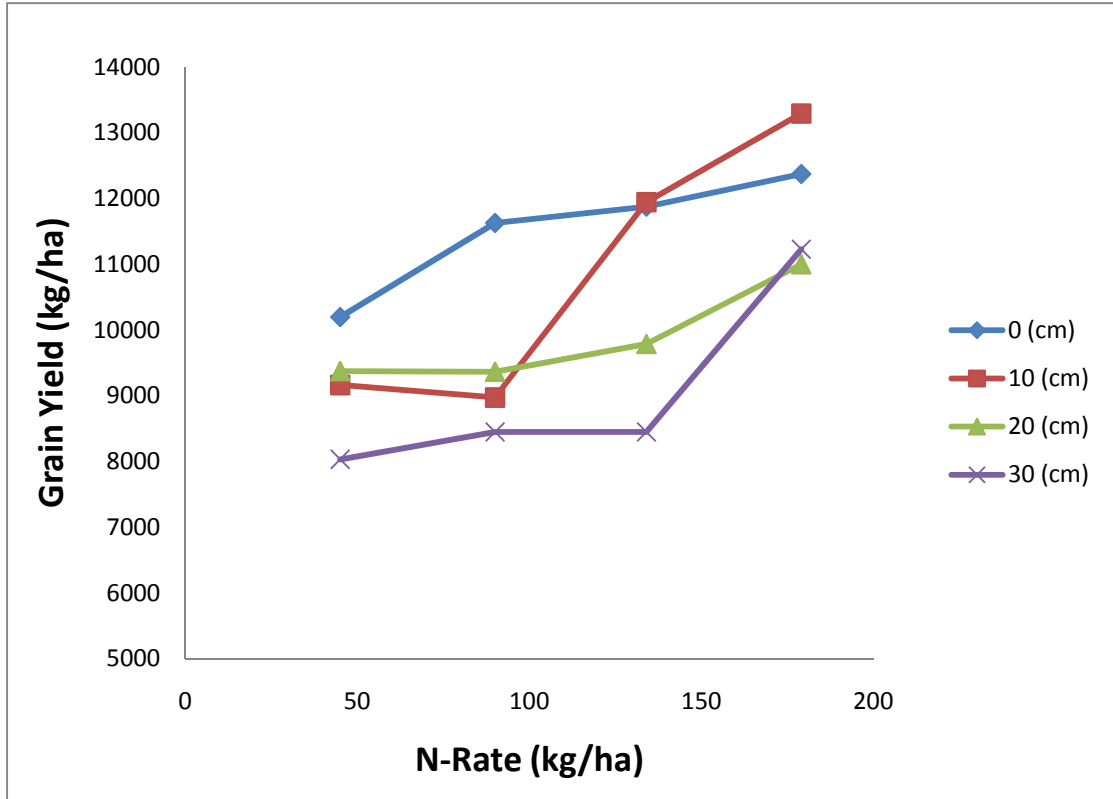


Table 1: Results of the analysis of variance when evaluating N-rate, application distance, and the interaction between N-rate\*application distance on corn grain yields R.L. Westerman 2008 and 2009 Irrigated Research Station, Stillwater OK.

Source of Variation	Degrees of Freedom	Mean Squares	Pr > F
Rep	2	9028468	0.5125
N-rate	3	34477953	0.0605
Application Distance	3	17519372	0.2781
N-rate*Application Distance	9	3396568	0.9845
Error	71	13378984	

## VITA

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Institution: Oklahoma State University

Location: Stillwater, Oklahoma

Title of Study: MAIZE (*ZEA-MAIZE L.*) GRAIN YIELD RESPONSE TO NITROGEN APPLIED AT DIFFERENT DISTANCES AWAY FROM THE ROW

Pages in Study: 44

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Major Field: Plant and Soil Science

Scope and Method of Study:

Traditionally midseason fertilizer nitrogen (N) applications in corn are placed down the center of a 76 cm row, making the distance of application 38 cm from the plant. This study was conducted to determine maize grain yield response to N placed at varying distances from the row, as well as specifically applying UAN (28%) directly to the plant stalk 13 cm vertically from the soil surface along a horizontal plane. Nitrogen rates were 45, 90, 134, and 224 kg N ha<sup>-1</sup> placed at distances of 0, 10, 20, 30 and 38 cm from the row. The effect of N placement (distance) within the row was investigated at the R.L. Westerman Irrigation Research Facility near Stillwater, Oklahoma and at Haskell, Oklahoma. Twenty treatments, consisting of varying N rates and variable distances within the row were used to evaluate corn grain yield response.

Findings and Conclusions:

When applying UAN to the soil surface using conventional tillage methods under irrigated conditions it is beneficial to corn grain yields to apply midseason N closer to the planted row. Substantial benefits were seen when midseason applications were placed at the base of the plant (0-cm) and the 10 cm application distances; however, it is not fully understood why the 10 cm application distance only produced higher corn grain yields at the two highest midseason application rates ( 134 and 179 kg N ha<sup>-1</sup> ). Furthermore, it should be understood that these results are probably highly dependent on soil texture and could be further affected by such factors as variable soil bulk densities (anthropogenic).

ADVISER'S APPROVAL: Dr. Bill Raun

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